

# **GROUND MOTION ATTENUATION RELATIONS FOR THE CENTRAL AND EASTERN UNITED STATES**

Award Number: 99HQGR0098

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Program Element: I. Products for Earthquake Loss Reduction

Key Words: Source characteristics, Strong ground motion, Regional seismic hazards

## **Investigations Undertaken**

The objective of this project is to develop ground motion attenuation relationships for the central and eastern United States for use in future revisions of the National Seismic Hazard maps produced by the USGS. In the first year of the project, we developed earthquake source models for use in generating ground motions. The source models have spatially varying slip distributions on the fault plane, and are described by self-similar scaling relations between seismic moment and source parameters such as fault dimensions and rise time derived from the slip models of three recent earthquakes in eastern Canada. We have now generated suites of ground motion time histories using these source models. The broadband time histories are calculated using a representative crustal structure model and ranges of source parameter values consistent with the source scaling relations. We are now using the broadband simulations to generate ground motion attenuation relations.

## **Results**

The source scaling relations for eastern North American earthquakes obtained in the first year of the project are listed in Table 1. We have used these source scaling relations to generate ground motion time histories. In Table 2, we list the parameters that we used to simulate ground motion time histories. These parameters are designed to provide an adequate sample of the ground motion conditions that the ground motion attenuation relations are required to represent. We are now developing ground motion attenuation relations for use in eastern North America using the simulated ground motion time histories.

To simulate ground motion time histories, we use a broadband Green's function method that has a rigorous basis in theoretical and computational seismology and has been extensively validated against recorded strong motion data (ref.). The earthquake source is represented as a shear dislocation on an extended fault plane, whose radiation pattern, and its tendency to become subdued at periods shorter than about 0.5 sec, are accurately represented. Wave propagation is represented rigorously by Green's functions computed for the seismic velocity structure which contains the fault and the site, or by empirical Green's functions derived from strong motion recordings of small earthquakes. These Green's functions contain both body waves and surface waves. The ground motion time history is calculated in the time domain using the elastodynamic representation theorem.

This involves integration over the fault surface of the convolution of the slip time function on the fault with the Green's function for the appropriate depth and distance. To simulate broadband time histories, the ground motions are computed separately in the short period and long period ranges, and then combined into a single broadband time history. The use of different methods in these two period ranges is necessitated by the observation that ground motions have fundamentally different characteristics in these two period ranges.

**Table 1. Scaling Relations of Slip Models of Crustal Earthquakes in Eastern North America**

Rupture Area vs. Seismic Moment:	$A = 8.9 \times 10^{-16} \times M_o^{2/3}$
Average Slip vs. Seismic Moment:	$D = 3.9 \times 10^{-7} \times M_o^{1/3}$
Combined Area of Asperities vs. Seismic Moment*	$A_a = 2.0 \times 10^{-16} \times M_o^{2/3}$
Area of Largest Asperity vs. Seismic Moment*	$A_l \text{ (km}^2\text{)} = 1.4 \times 10^{-16} \times M_o^{2/3}$
Radius of Largest Asperity vs. Seismic Moment*	$r_l \text{ (km)} = 6.7 \times 10^{-9} \times M_o^{1/3}$
Average Number of Asperities*	2.6
Area of Fault Covered by Asperities*	0.22
Average Asperity Slip Contrast*	2.0
Hypocentral Distance to Center of Closest Asperity Vs. Moment*	$R_A = 1.35 \times 10^{-8} \times M_o^{1/3}$
Slip Duration vs. Seismic Moment	$T_R = 3.75 \times 10^{-9} \times M_o^{1/3}$
Spatial Wavenumber Along Strike (1/km)*	$\log k_x = 1.92 - 0.5 M$
Spatial Wavenumber Down Dip (1/km)*	$\log k_y = 2.13 - 0.5 M$

\* assumed to be the same as for shallow crustal earthquakes in tectonic regions

**Table 2. Parameters used in Ground Motion Simulations**

PARAMETER	RANGE OF VALUES
Magnitude	Mw 5.0 - 7.5
Other Source Parameters	Scaling with magnitude is described in Table 4
Distance	0 - 500 km
Crustal Structure	Midcontinent model: $\alpha$ , $\beta$ , $\rho$ , $Q(h)$ ; K
Site Condition	Hard Rock ( $V_s = 2.8$ km/sec); $S_B/S_C$ boundary ( $V_s = 0.76$ km/sec)
Depth	5.0 - 30.0 km
Mechanism	Reverse; Strike-slip
Site Location (Reverse Faults)	Foot wall; Hanging wall
Directivity Function $X \cos \theta$ or $Y \cos \phi$	0.0 - 1.0

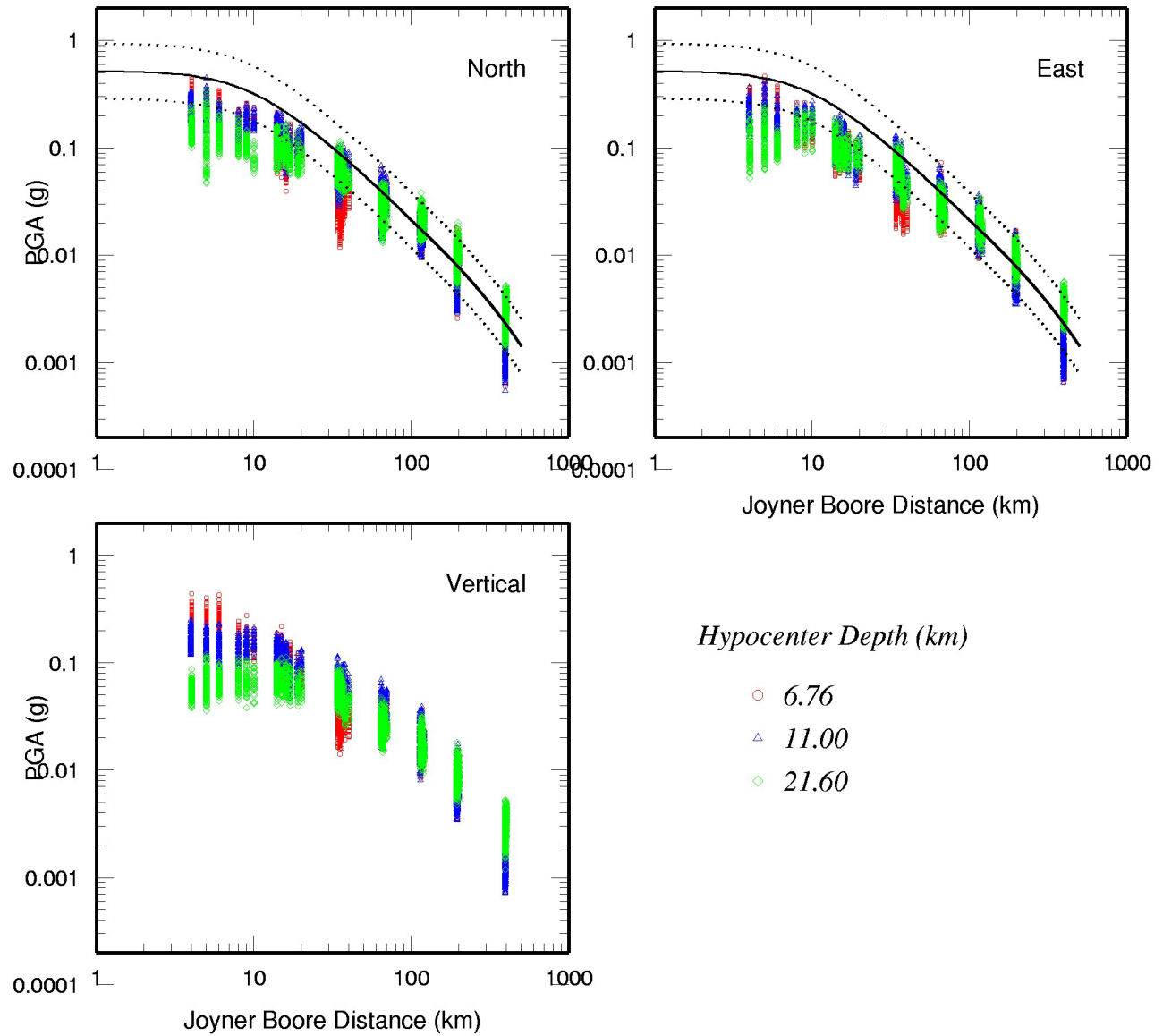
Examples of the ground motion simulations are shown in Figures 1 through 3. Figures 1 and 2 show the attenuation of peak acceleration with distance for magnitude 6 and 7 earthquakes for three different focal depths. The attenuation model of Toro et al. (1997), derived from stochastic simulations, is shown for comparison with the results of our simulations. Figure 3 shows response spectra averaged over all slip models, depths and hypocenter locations, for magnitude 6 and 7 earthquakes at a closest distance of 40 km.

### **Non-Technical Summary**

The objective of this project is to develop ground motion attenuation relations for the central and eastern United States for use in future revisions of the National Seismic Hazard maps produced by the USGS. The ground motion attenuation relations describe the dependence of the strength of the ground motions on the earthquake magnitude and on the distance from the earthquake. In the first year of the project, we developed earthquake source models for use in generating ground motions. The source models were derived from the slip models of three recent earthquakes in eastern Canada. In the second year of the project, we have generated suites of ground motion time histories that will be used to generate ground motion attenuation relations. The broadband time histories are calculated using a representative crustal structure model and ranges of earthquake source parameter values consistent with the source scaling relations.

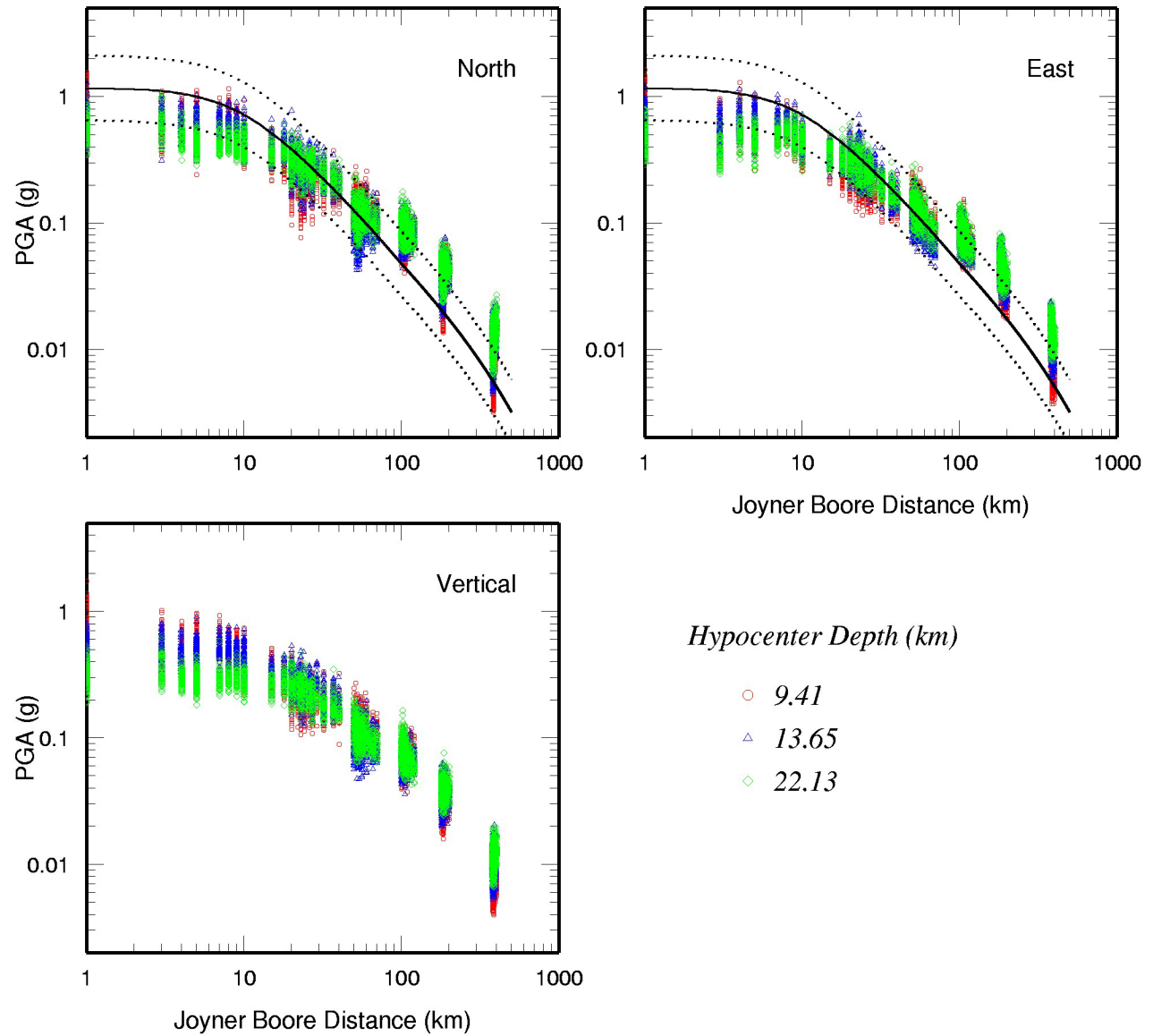
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*Broadband: Mw 6.0*  
*All Slip Models, Hypocentral Depths and Locations Along Strike*  
*Filter Parameters: 0.3 Hz for HF and 3.0 Hz for LP*  
*Attenuation Relation = Toro et al. 1997, Mid Continent Moment Magnitude Model*

Figure 1. Attenuation of peak acceleration, Mw 6.0.



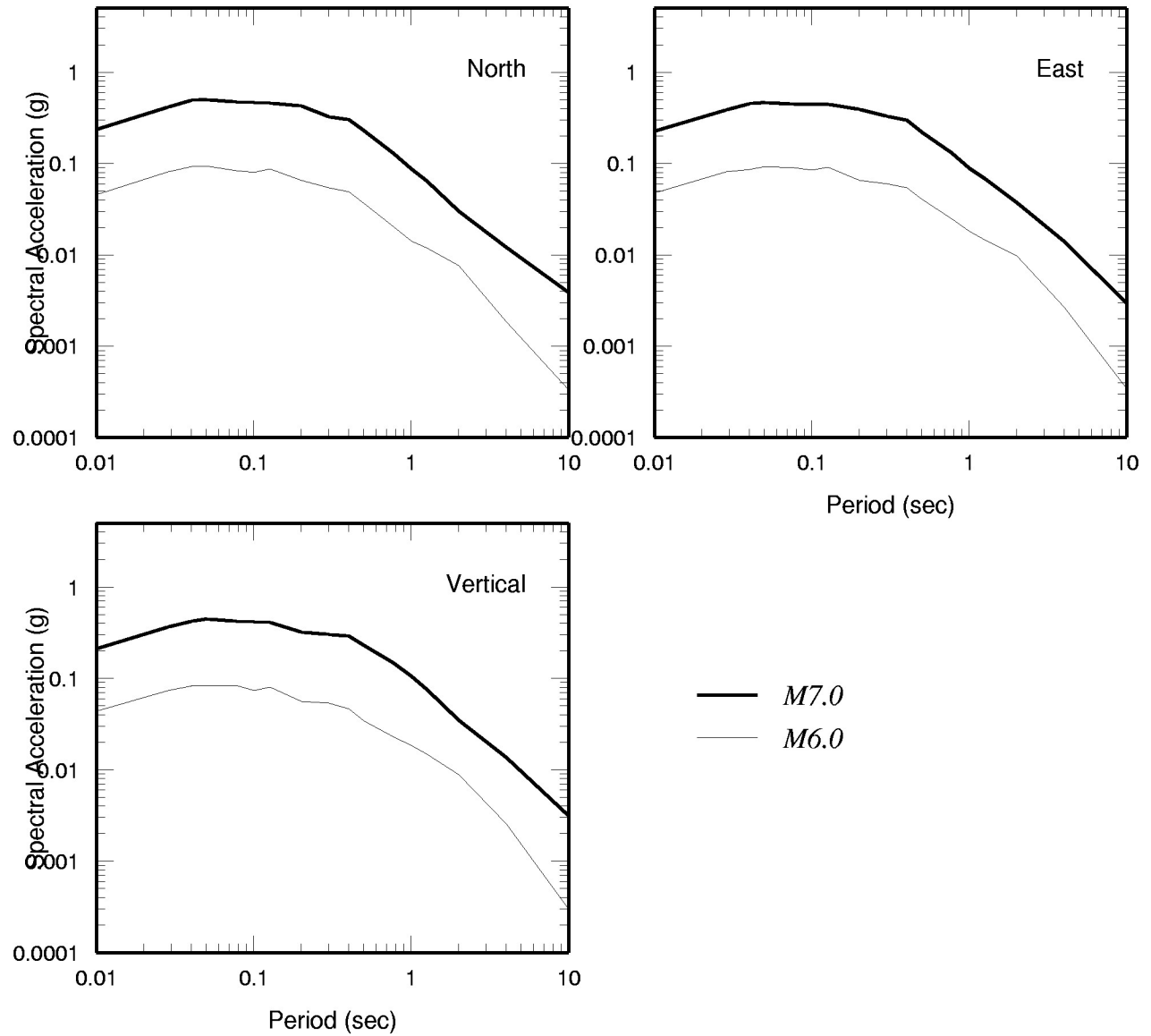
*Broadband: Mw 7.0*

*All Slip Models, Hypocentral Depths and Locations Along Strike*

*Filter Parameters: 0.3 Hz for HF and 3.0 Hz for LP*

*Attenuation Relation = Toro et al. 1997, Mid Continent Moment Magnitude Model*

Figure 2. Attenuation of peak acceleration, Mw 7.0.



*Broadband*  
*040 km Station Averaged Over All Slip Models, Depths, and Hypocenters*  
*Filter Parameters: 0.3 Hz for HF and 3.0 Hz for LP*

Figure 3. Response spectra for Mw 6.0 and 7.0, 40 km.